AD-A158 311 THIN SUPERCONDUCTING FILM CHARACTERIZATION BY SURFACE ACOUSTIC WAVES(U) WISCONSIN UNIV-MADISON DEPT OF PHYSICS M LEVY 22 APR 85 AFOSR-TR-85-0528 1/1

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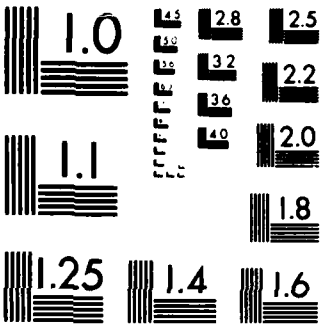

MICROCOPY RESOLUTION TEST CHART

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thin film superconductor
SAW
superconducting energy gap
vortex antivortex bound pairs
surface acoustic waves
electron phonon interaction
electron mean free path
amorphous superconductors

(OVER)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Both the dc electrical resistivity and the attenuation of surface acoustic waves (SAW) were measured in the superconducting state of a granular lead film as a function of an applied magnetic field normal to the film plane. At 4.2 K the data appear to yield an upper critical of about 60 K Gauss and a lower critical field of about 20 K Gauss.

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19. Key Words - continued

granular films
superconducting superlattice films
transition metal superconductors
upper critical field
granular lead film
renormalized dielectric junction
ferromagnetic superconductor
crystalline electric fields
very pure vanadium single crystal
Pb
zero temperature energy gap
BCS
submillikelvin temperatures
4GHz
acoustoelectric effect
layered compounds
A15 superconductors
Nb_3Ge
Aluminum nitride
ferromagnetism
amorphous molybdenum films
single crystal of $ErRh_4B_4$
interdigital electrodes
Va_3Sn
artifically produced superlattices of Nb and Zr
heavy fermion superconductor
pure Nb single crystal films
effective energy gap
piezoelectric coupling

Josephson junction networks
spin [illegible]
magnetic field
lower [illegible]
renor[illegible]
NbN fil[illegible]
$Er_x Ho$[illegible]
tern[illegible]
Nb
Hg
$2\Delta(0)$
super[illegible]sition temp[illegible]re
dilution [illegible]
auto[illegible] and attenuation measu[illegible] apparatus
stron[illegible] superconductors
chevrel phase superconductors
Nb_3Sn
lithium niobate
superconductivity
tin based ternary single crystals
single crystal of $Cu_2Mo_6S_8$
piezoelectric substrate
artifically produced superlattices of Nb and Cu
proximity effect
superinsulated dewars
strongly localized superconductor
sheet resistivity

$Er(x)\,Ho(1-x)\,Rh_4B_4$

20. Abstract - continued

A theoretical model that takes into account renormalization has been developed for explaining the SAW attenuation in a superconducting NbN film with a sheet resistivity of 30 kΩ/sq. Bulk ultrasonic measurements in the ferromagnetic superconductors $Er_xHo_{1-x}Rh_4B_4$ indicate that spin phonon interaction increases in the superconducting state of these ternary compounds. Ultrasonic measurements in very pure vanadium single crystals provide low temperature data which yield a zero temperature energy gap $2\Delta(0)$ that is very close to the BCS value of 3.5 kT_c but the data close to the superconducting transition temperature T_c would yield $2\Delta(0) = 4.2\ kT_c$. A theoretical model is being investigated to ascertain if it will resolve this apparent discrepancy.

The research goals and objectives of this investigation will remain the same. No significant reorientations are anticipated for the second and third years of this research project.

RESEARCH OBJECTIVES AND APPROACHES

The objective of this investigation is to characterize thin film superconductors with surface acoustic waves (SAW). By measuring the electron phonon interaction in thin films, the temperature dependence of the superconducting energy gap and the electron mean free path may be determined. It may also be possible to determine the existence of vortex and vortex bound pairs in amorphous superconductors and the effective energy gap in strongly localized superconductors. By measuring the piezoelectric coupling to the sheet resistivity of granular films it may be possible to determine the size distribution of the granules and the distribution of the coupling between granules. Surface acoustic wave measurements of Josephson junction networks may be correlated with their signal processing properties. SAW measurement of superconducting superlattice films may provide information about the mechanical properties of these films. Measurements with bulk waves will provide information about spin phonon coupling in magnetic superconductors and electron phonon interaction in the transition metal superconductors.

ACCOMPLISHMENTS

Both the dc electrical resistivity and the surface acoustic wave (SAW) attenuation coefficient were measured in the superconducting state of a granular lead film as a function of an applied magnetic field normal to the film plane at several constant temperatures. An analysis of the data based on our flux model appears to yield type II magnetization curves with upper critical fields for this granular lead film which are as high as 60 K Gauss, and lower critical fields of about 20 K Gauss at 4.2 K.

We have evolved a theoretical model that takes into account renormalization to explain the experimental discrepancy in the superconducting state between the SAW attenuation in a NbN film and its sheet resistivity. The film has a BCS transition temperature of about 10 K, and a Kosterlitz Thouless transition temperature of 5 K, and a normal state sheet resistivity of 30 KΩ/sq. An exact solution has been found for the renormalized dielectric function of a two dimensional superconductor which has Kosterlitz Thouless flux line dipoles.

Bulk ultrasonic measurements in the series of ferromagnetic superconductors $Er_xHo_{1-x}Rh_4B_4$ (received from Dr. Brian Maple, UCSD) appear to indicate that spin phonon interaction is supressed by crystalline electric fields but superconductivity screens these fields permitting the interaction to appear. This may be the reason for the increase in attenuation that we have observed in the superconducting state of these ternary compounds.

Ultrasonic measurements on very pure vanadium single crystals (received from Dr. Frederick Schmidt, Iowa State University) exhibit data similar to that found for pure crystals of Nb, Pb and Hg . Analysis of the low temperature data yields a zero temperature energy gap $2\Delta(0)$ that is very close to the BCS value of 3.5 kT_c while analysis of the high temperature data close to the superconducting transition temperature T_c yields a larger value for $2\Delta(0)$. For pure single crystals of vanadium we find this value to be $2\Delta(0) \simeq 4.2\ kT_c$. It may be that a model based on the effect of renormalization in the superconducting state may be able to explain this discrepancy.

One paper has been submitted to the Physical Review, one paper to Phys. Rev. Letters and another is being prepared for submission to the Physical

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Review. Two additional papers have been submitted to the International Conference on Materials and Mechanisms of Superconductivity to be held in Ames, Iowa on May 29-31, 1985. And, an invited paper and two contributed papers have been submitted to the Eighth International Conference on Internal Friction and Ultrasonic Attenuation in Solids to be held at Urbana, Illinois on June 3-6, 1985.

FORECAST

The research goals and objectives of this investigation will remain the same. The number of graduate research assistants will be maintained at the same level. The rate of expenditure of funds is expected to continue at the proposed level. No significant reorientations are anticipated for the second and third years of this research project.

When the equipment provided by DOD-URIP Grant No. 84-0221 is assembled it will be possible to carry out these measurements down to sub millikelvin temperatures and up to frequencies of 4 GHz. The dilution refrigerator has been ordered from Oxford Instruments and is expected in a few months. The automatic velocity and attenuation measurement apparatus up to frequencies of 160 MHz has been ordered from Matec. A schematic and list of the equipment necessary to extend the frequency range up to 4 GHz is being designed in collaboration with Matec and assembled at UNH. Several options for a computer to interface with this equipment are being investigated. Because of delays at the manufacturers, an additional cost extension beyond 15 July 85 will be necessary and has been requested.

TECHNICAL PERSONNEL

In addition to the principal investigator, the following graduate students have worked and will be working on this grant. The university has supported some of them as part of their matching commitment.

Full Time:

Mr. Anders Schenstrom	(Senior Graduate Research Assistant) Theoretical renormalization model for acousto-electric effect in superconducting NbN, and SAW investigation of granular films and superlattices.
Mr. Jeff Schmidt	(Senior Graduate Research Assistant) SAW investigation of granular Pb films and amorphous films.
Mr. Keun-Jenn Sun	(Senior Graduate Research Assistant) Ultrasonic investigation of ternary ferromagnetic superconductors and pure vanadium single crystals.
Mr. Roy Wiegert	(Senior Graduate Research Assistant) Responsible for assembling automatic ultrasonic attenuation and velocity measuring apparatus. (DOD-URIP Grant No. 84-0221)

Part Time:

Mr. Hugues-Pierre Baum	(Junior Graduate Research Assistant) Will work on layered compounds, strong coupled superconductors, and A15 superconductors.
Mr. Qiang Qian	(Junior Graduate Research Assistant) Will work on dilution regrigerator. (DOD-URIP Grant No. 84-0221)
Mr. Dale Walikainen	(Junior Graduate Research Assistant) Will work on Josephson coupled superconducting arrays.
Mr. Min Feng Xu	(Junior Graduate Research Assistant) Will work on single crystal vanadium, ternary alloys and chevrel phase superconductors.

SCIENTIFIC INTERACTIONS

1. Nb_3Sn and Nb_3Ge Films

For our research, Dr. Robert Hammond, Stanford University, will attempt to deposit Nb_3Ge films on aluminum nitride substrates. He will also attempt to deposit Nb_3Sn and Nb_3Ge films on perovskite lithium niobate substrates.

2. Ternary Alloys

Polycrystalline Samples of $Ho_xLr_{1-x}Rh_4B_4$ have been obtained from Professor Brian Maple, U.C. San Diego. These samples have a ferromagnetic transition temperature that is accessible with a He^4 cryostat. Therefore, the interplay between ferromagnetism and superconductivity can be more easily investigated ultrasonically.

3. Amorphous Superconductors

We have obtained from Professor Ted Geballe and Robert Hammond, Stanford University, amorphous molybdenum films stabilized with a small amount of niobium, which were deposited on quartz and lithium niobate substrates. Interdigital electrodes will be deposited on the substrates and preliminary measurements will be initiated.

4. Tin Based Ternary Single Crystals

We obtained from J. P. Remeika, Bell Laboratories, single crystals of tin based ternary single crystals that are both magnetic and superconducting. These crystals will permit the transmission of higher frequencies than in the polycrystalline ternary alloys. The frequency dependence of the attenuation coefficient should make it possible to distinguish between different models that have been proposed to explain the observed effects. Initial attempts at polishing the samples have shown them to be extremely

brittle. New samples have been obtained from J. P. Remeika. A He^3 probe has been built and tested for these measurements. Preliminary measurements have been performed but the crystals still do not appear adequate for obtaining ultrasonic data.

5. Single Crystals of the Ternary Alloys

Continued discussions with Dr. David Hinks, Argonne National Laboratory, concerning the possibility of obtaining single crystals of the ternary alloys. The first crystals will be of $ErRh_4B_4$. These crystals will also be measured with the He^3 probe.

6. Single Crystal of $Cu_2Mo_6S_8$

Correspondence with Dr. Renee Flukiger, Solid State Institute, Karlsruhe, concerning the possibility of obtaining a single crystal of $Cu_2Mo_6S_8$ was conducted. He has grown such as crystal and hopefully it will be sent to us for characterization.

7. Array of Josephson Coupled Superconductors

Discussions were held with Professor R. S. Newrock, University of Cincinnati, concerning the deposition of an array of Josephson coupled superconductors on a piezoelectric substrate. Interdigital electrodes will then be evaporated on this substrate in order to investigate the array with surface acoustic waves in the 700 MHz frequency range.

8. Films of Va_3Sn

Discussions were initiated with Dr. John Gavaler, Westinghouse, about obtaining thin films which will be measured with surface acoustic waves. Two substrates covered with films have been obtained.

9. Artificially Produced Superlattice

Discussions were initiated with Dr. Ivan Schuller, Argonne National Laboratories, about the possibility of obtaining superlattices made of Nb and Cu in order to investigate their characteristics with surface acoustics waves. Similar discussions were held with Professor Ted Geballe and Dr. Robert Hammond, Stanford University, to obtain superlattice structures of Nb and Zr.

10. 1984 IEEE Ultrasonic Symposium

On November 14-16 chaired session at the Dallas, Texas, conference.

11. Visit to Physics Department, University of Illinois, Urbana

Presented seminar on November 20, 1984

"Surface Acoustic Wave Investigation of Superconducting Films."

Discussed measurements on superconducting films with Professor Dan Ginsberg and measurements in the mixed superconducting state with Professor Andrew Granato. Visited the low temperature labs and discussed the installation of their dilution refrigerators because of the installation we were planning for our new refrigerator (DOD-URIP Grant No. 84-0221).

12. During travel in Europe Professor Levy made visits to the following:

12.1 Visit to the Institute of Physical Chemistry, Polish Academy of Sciences, Warsaw, Poland

On December 27, 1984 presented seminar on

"Surface Acoustic Waves."

Visited the surface studies laboratory.

12.2 Visit to Swiss Federal Institute of Tech, Zurich, Switzerland

On January 4-5, 1985, visited the low temperature laboratory and discussed the merits of the SHE and Oxford dilution refrigerators installed at the labs there. Discussed with Dr. Hans Rudi Ott his measurements on heavy fermion superconductors and discussed with Dr. Ana Celia Mota her measurements on the proximity effect at millikelvin temperatures. Also discussed these topics with Professor Jorgen L. Olsen.

12.3 Visit to the Bavarian Walther Meissner Low Temperature Laboratory, Munich, West Germany

On January 7 and 8, 1985, Professor Levy visited the Walther Meissner Low Temperature Laboratory and discussed with the director, Dr. Klaus Andres, the merits of their different large dilution refrigerators and the advisability of building specialized small dilution refrigerators and using superinsulated dewars for these small refrigerators in order not to require liquid nitrogen in their operation.

13. 1985 IEEE Ultrasonic Symposium

Member of the program committee of the conference to be held in San Francisco on October 16-18, 1985.

14. March Meeting of the American Physical Society

Attended the conference on March 25-29, 1985, which was held in Baltimore, Maryland and chaired a session on "Superconductivity: A15 Compounds." Held discussions with Professor Ted Geballe, and Dr. Robert Hammond, Stanford University, concerning superlattices of Nb and Zr. Held discussions with Dr. John Gavaler about measuring some of their pure Nb

single crystal films in order to establish a standard comparison with the A15 superconducting films. Held discussions with Dr. George Crabtree, Argonne National Laboratory, about the single crystals of $ErRh_4B_4$ that they are attempting to grow at Argonne National Laboratory. Discussed with Professor R. Newrock his continuing attempts to make Josephson coupled arrays. They are going to use the Cornell submicron facility to produce these arrays. Discussed with Dr. Ana Celia Mota the possibility of making surface acoustic wave measurements on systems which display the large superconducting proximity effect that she recently discovered. Continued discussions with Dr. Jim Smith, Los Alamos Laboratory, about the possibility of obtaining heavy fermion superconducting crystals from him for ultrasonic measurements. Discussed our bulk wave measurements on the ternary superconductors and our SAW measurements on granular superconductors with Dr. Lewis Testardi, National Bureau of Standards.

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